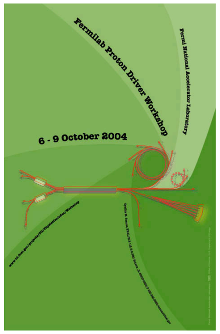
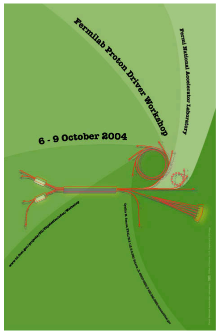


Tevatron Working Group Session Summary

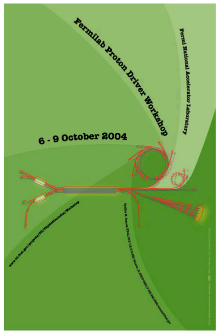
- Physics Topics
- Accelerator Physics
- Summary

Conveners: Harry Cheung, Penny Kasper, Peter Ratoff



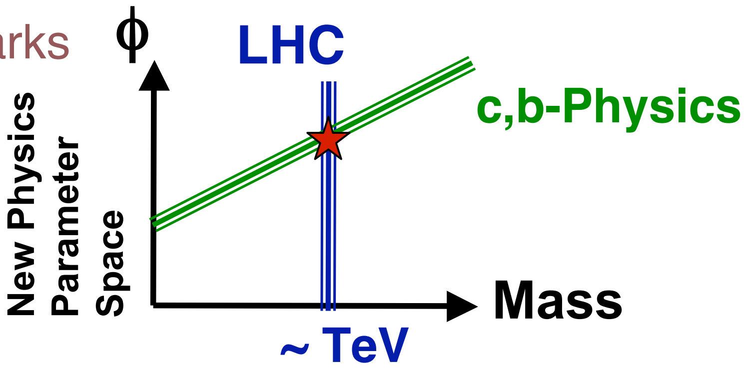
Goal of Tevatron WG(6)

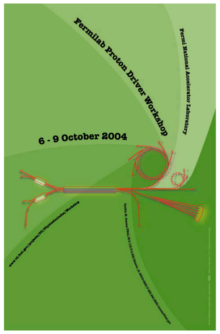
- "Charge" to the working group:
  - Investigate the physics opportunities at the Tevatron with the addition of a 2MW proton driver to the Fermilab accelerator complex. (What is the breadth of physics case for a PD.)
  - Take 3-10 as the factor of intensity/luminosity gain for consideration
  - Take after 2015 as the time period to consider
- Program of a small number of very good focused talks:
  - Not an obvious area to look at, small attendance in WG6
  - Want to thank all the speakers for all giving very good talks and for their hard work in preparing them (quote: "was fun to think about")



Charm and Bottom Physics in 2015 and Beyond

- Excellent talk from Ulrich Nierste (Fermilab):
  - Charm and bottom is still interesting in the LHC era, and even with an ILC.
    - FCNC can probe scales up to 100 TeV
    - Want to determine parameters of the flavour sector to help sort out which type of "New Physics" scenario is discovered at the LHC. (Complementary knowledge)
    - E.g. difficult to do FCNC with squarks
  - Want to study theoretically clean observables and very rare processes
    - Gave specific examples





$D-\overline{D}$ mixing

Mixing parameters:

$$x \equiv \frac{\Delta m_D}{\Gamma_D}, \qquad y = \frac{\Delta\Gamma_D}{2\,\Gamma_D}$$

Standard Model predictions:

$$x \lesssim y \lesssim 10^{-2}$$ Bigi, Uraltsev; Falk et al.

$\Rightarrow$ Precision measurements of x and y far below the percent level are not useful.

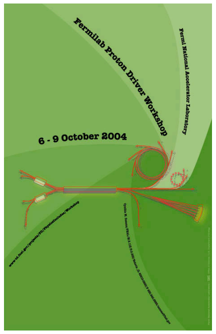
Better: Mixing-induced CP asymmetries (in, say, $D^0 \to KK, K\pi, \pi\pi \ldots$):

$$A_{CP} \sim 2(x\cos\delta + y\sin\delta)\,\sin\phi\,\Gamma_D\,t,$$

where δ is a strong rescattering phase. In the Standard Model the $D-\overline{D}$ mixing phase ϕ is tiny: $\phi \lesssim 10^{-3}$. In new physics scenarios $-1 \leq \sin\phi \leq 1$.

Also D rare decays

Ulrich Nierste Charm and bottom physics in 2015 and beyond Seite 11



B decays no longer motivated by "unitarity triangle trigonometry"

An important example for a "near zero" prediction of the Standard Model is the CP asymmetry in decays $B_s \to f$ which are flavor-specific, i.e.

$$\overline{B}_s \not\to f \text{ and } B_s \not\to \overline{f}.$$

Examples: $B_s \to X\ell^+\nu_\ell$ or $B_s \to D_s^-\pi^+$.

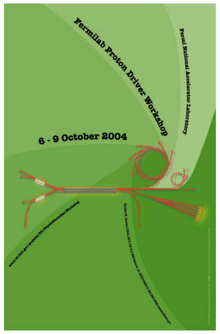
In the Standard Model:

$$a_{\rm fs} = 2 \cdot 10^{-5} \propto |V_{us}|^2 \frac{m_c^2}{m_b^2}$$

Beneke, Buchalla, Lenz, U.N.

The suppression factor $|V_{us}|^2 m_c^2/m_b^2$ is absent in new physics scenarios with new non-CKM contributions to $\mathrm{B_s}-\overline{\mathrm{B}}_\mathrm{s}$ mixing.

$\Rightarrow$ An enhancement by a factor of ~ 200 to $a_{\rm fs} \sim 5 \cdot 10^{-3}$ is possible.



Rare leptonic decays:

A measurement of any of

$$B_d \to \mu^+\mu^-, \qquad B_d \to \tau^+\tau^-,$$
$$B_s \to \mu^+\mu^-, \qquad B_s \to \tau^+\tau^-,$$

will constrain the supersymmetric Higgs sector. For large $\tan\beta$ the neutral Higgs couplings are probed. The simultaneous measurement of several of these leptonic decay modes will quantify the deviation from minimal flavor violation.

Standard Model: $Br(B_s \to \mu^+\mu^-) = (4 \pm 1) \times 10^{-9}$ Buchalla, Buras

Conversely

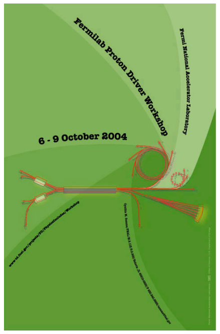
$$B^+ \to \mu^+\nu_\mu, \qquad B^+ \to \tau^+\nu_\tau,$$

probe the charged Higgs sector of supersymmetric and other multi-Higgs models.

The decay constant f_B drops out from ratios like

$$Br(B_d \to \mu^+\mu^-)/Br(B^+ \to \mu^+\nu_\mu)$$

rendering them theoretically very clean.



From Uli's talk:

4. Summary

- In 2015 and beyond precision B physics will probe the flavor structure of the new particles found by the LHC. If the world is supersymmetric, flavor physics will teach us something about the SUSY breaking mechanism.
- There are quantities with hadronic uncertainties well below 1%, which are suitable for precision determinations of fundamental parameters. These include certain CP asymmetries and ratios of certain branching fractions.
- A further long-term goal of charm and bottom physics are the "near zero" predictions of the Standard Model, where new physics can dominate. These include charm FCNC's, the CP asymmetry in flavor-specific B_s decays and rare decays like $B \to \ell^+ \ell^-$.
- The analysis of iso-spin violating new physics can best be performed at hadron colliders through e.g. $B_s \to \phi\pi^0$, $B_s \to \phi\rho^0$, $\Lambda_b \to \phi\Lambda$.
- The opportunities of the proton driver for BTeV should be seriously explored.
- My talk covered only a few examples. There are many more interesting points for the flavor physics agenda in 2015 and beyond.

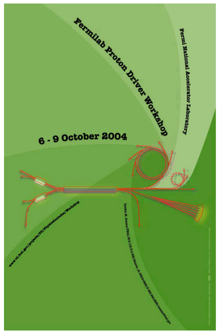
Very good physics to do but: Would these be done already?

Ulrich Nierste | Charm and bottom physics in 2015 and beyond | Seite 21

B Physics Landscape in 2015

- Data collected by BTeV and LHCb
  - Take talk from Sheldon Stone to P5 in July 2004:

	2007	2008	2009	2010	2011	2012	2013	2014	Sum
LHCb (2007 Start)	0.1	0.6	0.8	0.8	0.8	0.8	0.8	0.8	5.5
LHCb-2 (2008 Start)		0.1	0.6	0.8	0.8	0.8	0.8	0.8	4.7
BTeV				1.5	1.6	1.6	1.6	1.6	7.9

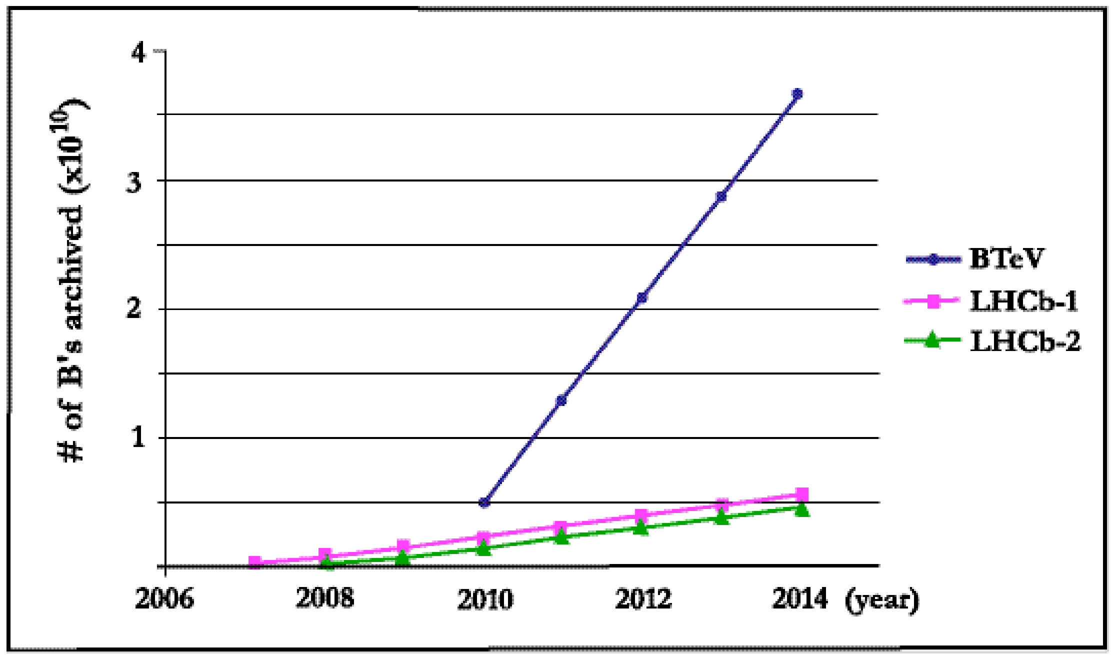


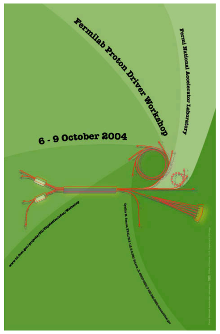
B Physics Landscape in 2015

- Production, and also detector, trigger and DAQ are quite different:
  - LHCb (2007 start) ~ 5×10^{12} b produced, ~ 0.5×10^{10} reconstructed
  - BTeV ~ 2×10^{12} b produced, ~ 2×10^{10} reconstructed

Just taking the b event rate (200 Hz LHCb and 1000 Hz BTeV) gives: (Plot from Stone)

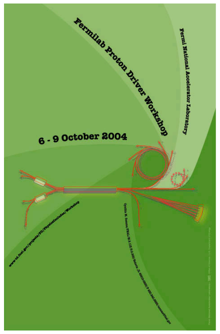
I need the numbers from LHCb for report!





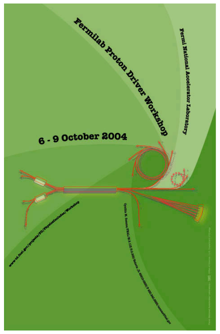
B Physics Landscape in 2015

- Would already have a done a lot of charm and beauty physics with BTeV and LHCb in 2015 - but can improve on very rare processes
- How could BTeV get more c and b decays?
  - Second arm gives 2 times more data
  - Near limit of number of interactions/crossing would need to reduce crossing time between bunches to take advantage of increase in luminosity, e.g. 396 ns to 132ns would give a factor of 3 increase. More would probably need major change in detector.
  - Could get 6 times more data relatively “easily”
- Need to get information from LHCb but they want one interaction/crossing



High p_T Physics Opportunities

- Two very nice talks:
  - Tim Tait (Argonne)
  - Bogdan Dobrescu (Fermilab)
- Tim Tait on High pT physics in 2015:
  - Much info in HCP2004 for ~ 300 fb^{-1}
  - Top Physics, Higgs Physics, Supersymmetry, Extra Dimensions, W's and Z's

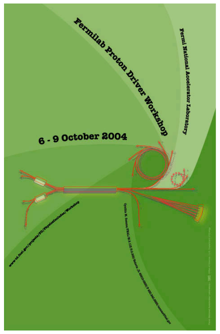


Tait's summary slide:

Summary

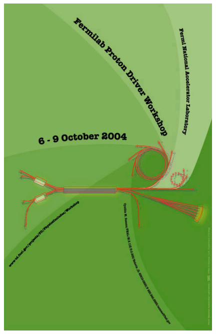
- In 2015 the LHC will have made great progress in exploring the high energy frontier.
  - Anomalous top physics should be discovered or bounded to 10^{-3} or so.
- If there is a SM-like (or MSSM-like) Higgs, probably we'll know.
  - Couplings could be measured to 10% (if we're lucky) or not measured (if we're not so lucky…)
  - Is it really the Higgs?
- If nature is supersymmetric, some sparticles should be seen.
  - Gluinos, squarks, some neutralinos/charginos seen and measured.
  - Higgsinos, sleptons, and maybe stops may be unknown.
  - SUSY Higgses may or may not be seen.
- Extra dimensions should be seen as KK modes, black holes, etc…
  - Black holes are messy.
  - UED represents a challenge to distinguish from SUSY
  - Z's/W's could be seen. How well will we know their interactions?
- We should have strong clues to EWSB, but a lot more to do!

Proton Driver Workshop, 10/7/04 | Tim Tait | 18



High p_T Physics Opportunities

- Bogdan Dobrescu opportunities in 2015:
  - Hard to compete with LHC
  - Even harder to compete with LHC + ILC
  - Tevatron has smaller backgrounds and more pbars per collision
    - Need very high luminosity
    - There are examples of physics beyond the SM where the Tevatron is useful after the LHC
    - Can always find some physics scenario but cannot tell how likely these scenarios are!
    - Gave some examples



Slide from Bogdan:

Light Stop in the MSSM

Demina, Lykken, Matchev, Nomerotski, hep-ph/9910275

Typically: $\tilde{t} \rightarrow t\chi_1^0$

For $m_{\tilde{t}} < m_t + m_\chi$:

$\tilde{t} \rightarrow c\chi_1^0$ is the dominant decay mode

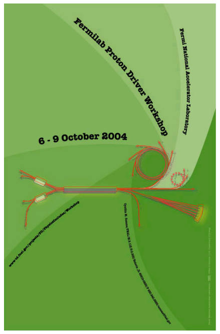
Stop searches in Run II: $\tilde{t}\tilde{t}^\star \rightarrow c\bar{c}\,\not{E}_T$

Challenging at the LHC because of large backgrounds.

Slide from Bogdan:

Leptophobic Z', e.g., $U(1)_B$

- No significant bound from LEP or ILC
- LHC has large dijet background
- The Tevatron with high luminosity has probably the best chance of discovering a leptophobic Z'.



Taken from Slides from Bogdan:

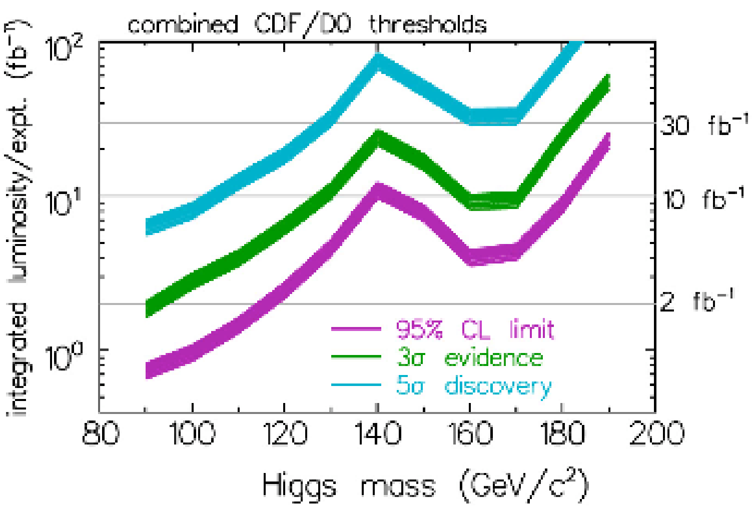
Higgs bosons

For 115 GeV $< M_h <$ 130 GeV:

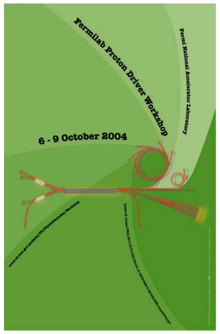
the Tevatron may measure the $h\bar{b}b$ coupling

Associated production $(q\bar{q} \to W^* \to hW)$ with $h \to \bar{b}b$

At the LHC: huge $\bar{b}b$ background.

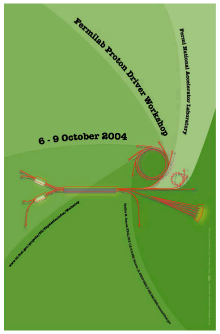


Could be interesting physics opportunities but they require very large datasets ~ 100 fb-1



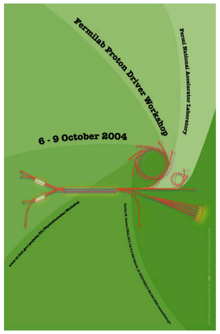
QCD at the Tevatron

- Two interesting talks from
  - Mike Albrow (Fermilab)
    - Already a QCD working group for TEV4LHC
    - Lots of interesting QCD physics that can be done at CDF or D0 with minor addition of forward detectors, or at BTeV (with some additions)
  - Ted Barnes (Univ. of Tennessee)
    - Lots of interesting QCD with different q and g states, exotic or otherwise
    - Meeting of the APS Hadron group at the end of Oct.
- Conclude that a PD does not really help



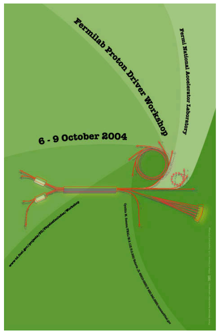
Fixed-target Tevatron Beams

- Beam of high energy neutrinos
  - Not much interest in this
- Hyperons (Jensen, Ramberg)
  - Lots of interesting rare and radiative decays to study, and look for CP violation
  - High energy much better than MI
    - Better EMCAL resolution
    - Cleaner hyperon beams
    - Better hyperon/anti-hyperon systematics
  - No gain from intensity (e.g. HyperCP only use $<10^{12}$ protons/min)
- Tau neutrinos
  - DONUT would want 200 more data to be useful, (2×10^{15} protons/min)
  - Higher energy is much better (e.g. LHC!)



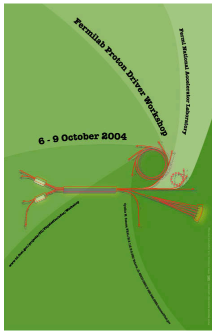
Accelerator Physics: What Luminosity/Intensity can we get?

- Initially looked at the TeV33 report from 1996 and saw they listed a changes to get to 10^{33} $cm^{-2}s^{-1}$:
  - Increasing number of antiprotons
  - Increasing number of bunches (# protons) in the Tevatron
- Two Excellent talks focused on these:
  - Paul Derwent (Antiproton Source Dept.)
  - Vladimir Shiltsev (Head of Tevatron Dept.)
- So what increase in Tevatron luminosity or proton intensity could we get?



Accelerator Physics: What Luminosity/Intensity can we get?

- Paul Derwent on Antiproton source:
  - Already implemented or will implement the changes listed in the TeV33 report to get to Run IIb luminosity
  - Not limited by the number of protons on target (to make antiprotons) - limited by cooling in the debuncher and the antiproton accumulator
  - Described the changes to be done to get to get to Run IIb antiproton rates, and gave a road map for how to increase the rates



Slide from Paul Derwent

Strategy

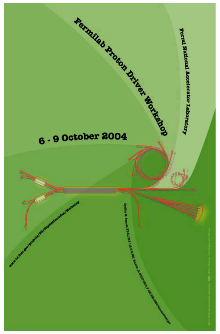
*** Present Operations**

- -> Accumulator: final repository for pbars
- -> Stochastic Cooling:
  - Cooling time ~ Number of particles
  - Limits
    - cycle time (Debuncher cooling)
    - stack size ~ 300e10
    - stacking rate falls off with stack size (gain and cycle time)
- -> Transfer to Tevatron ~ 1/day

*** Future Operations**

- -> Recycler : final repository for antiprotons
- -> Electron Cooling:
  - Cooling Time ~ Independent Number of particles
    - Stack Size: $\sim 600\times10^{10}$
    - Stacking Rate: ~ Independent of Stack size
- -> Accumulator:
  - Optimized for flux, not density
  - Smaller Stack size: $\sim 30\times10^{10}$
  - Still limited by cooling in Debuncher and stacktail
- -> Frequent (2/hour) transfers between Accumulator and Recycler
- -> Transfer to Tevatron ~1/day

Paul Derwent Proton Driver Workshop 6 Oct 2004



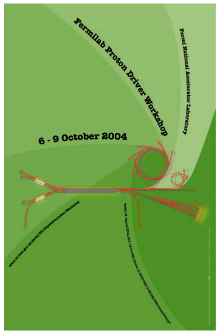
Slide from Paul Derwent

If everything worked perfectly...

* With proton driver, double beam on target (1.5 - 2 e13)
  - -> Collect all beam of target
    - Beam sweeping to keep target from disintegrating
  - -> Transport to Debuncher
  - -> Improve Debuncher Cooling performance (momentum and transverse) by ~factor 2
    - double beam intensity, halves cooling rate
    - double performance, meet initial specifications
    - Need another cooling orbit -- in Acc? new Ring?
  - -> Push Accumulator Stacktail to (beyond?) stability limits, transfer every 15 minutes
  - -> Improve Recycler cooling performance (transverse) by ~ factor 2
  - -> Improve Electron cooling rates by factor ~2
    - Doubling Pelletron current to 1 A
  - -> Push Recycler stability limits at expense of longitudinal emittance (roughly double)
  - -> 1e13 in 60eV-sec in 15 hour time period?
    - with significant upgrades over Run II Upgrade program

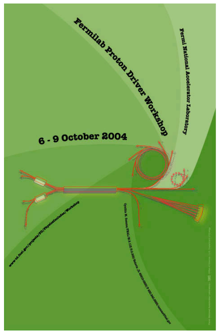
Paul Derwent Proton Driver Workshop 6 Oct 2004

Need (Big IF)^N to give 2× more antiprotons



Accelerator Physics: What Luminosity/Intensity can we get?

- Vladimir Shiltsev on if a PD can help the Tevatron:
  - Interested in integrated luminosity
    - Initial instantaneous luminosity
    - Luminosity lifetime



Luminosity and Integral

$$L = \frac{3\gamma\ f_0\,(B\,N_{\bar{p}})N_p}{\pi\beta^*\left(\varepsilon_p + \varepsilon_{\bar{p}}\right)} H\left(\sigma_l / \beta^*\right)$$

- Peak Luminosity: primary factors
  - Beta* at IP - no relation to PD
  - Total Antiprotons: BN_a - may be x2, see P.Derwent
  - Bunchlength: H(s/beta)
  - Emittances
  - Number of protons per bunch N_p

Shorter length bunches are focused better

AD Seminar: Tevatron in FY'04 and '05 - Shiltsev

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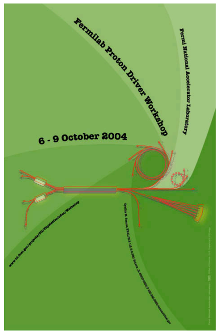
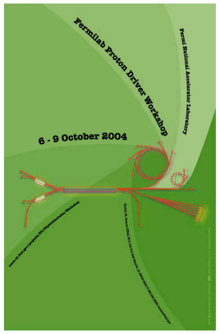


Accelerator Physics: What Luminosity/Intensity can we get?

- Vladimir Shiltsev on if a PD can help the Tevatron:
  - Interested in integrated luminosity
    - Initial instantaneous luminosity
    - Luminosity lifetime
  - Number of protons into the machine affects the luminosity lifetime, many parameters can affect this
    - Created a model to study the luminosity lifetime!



Luminosity Integral

$$I = \int L dt = N_{stores} \tau_L L_0 \ln(1 + T / \tau_L)$$

- Luminosity lifetime

$$\tau_L^{-1} = \tau_\varepsilon^{-1} + \tau_a^{-1} + \tau_p^{-1} + \tau_H^{-1}$$

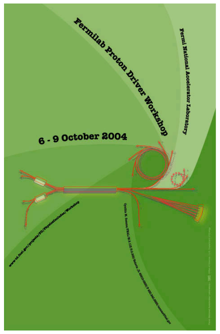
(15-20) + (20-25) +(35-210)+(70-80) =(7.5-9.0)hrs

- Emittance growth = 90% IBS + 10% Beam-Beam Effects
- Pbar lifetime = (70-80)% burnup + (20-30)% Beam-Beam
- Proton lifetime = 80% Beam-Beam + 20 % burnup
- Hourglass lifetime = 90% IBS + 10 % Beam-Beam

IBS constitutes 50% of luminosity lifetime

Beam-Beam Interaction reduces luminosity lifetime by 15-20%

AD Seminar: Tevatron in FY'04 and '05 - Shiltsev 7

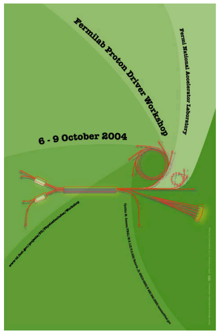


Slide from Vladimir Shiltsev

Now , Let's Count Everything:

▪ More pbars	x2 (if)
▪ More p's w/o BBC	17% - ?
▪ More P's with BBCompensation	20-50%
Total	x3 – "if" ^{2}

- A proton driver only gives an increase of 3× in the Tevatron integrated luminosity. (Even then needs major changes and $$$).
- Could get 25× increase in proton intensity for fixed-target experiments (Needs extraction region).



WG6 Summary

- Certainly lots of interesting charm and bottom physics, much will be done by BTeV and LHCb, and LHC should have made some discoveries. Unclear right now what is needed in 2015, i.e. if a PD helps.
- There are physics scenarios where the Tevatron is useful even in 2015 after LHC. Don't know how likely they are but they do need very high integrated luminosity, maybe in the region of 100 fb^{-1}.
- Not likely to gain much in Tevatron integrated luminosity with a Proton Driver. Fixed target proton beam intensities could increase by a factor of 25× (3×10^{14} protons/min).
- Lots of interesting QCD physics, and fixed-target experiments are possible but no gain from intensity.
- Only gain of the Proton Driver seems to be proton economics, i.e. allows an interesting physics program using the Tevatron even with a large neutrino program.

Conveners: Harry Cheung, Penny Kasper, Peter Ratoff